AIDS AND INCENTIVES TO THE ACQUISITION OF KNOWLEDGE.

THE

FAREWELL LECTURE

DELIVERED

ON RETIRING FROM THE

PROFESSORSHIP OF MATHEMATICS

IN

THE ROYAL MILITARY ACADEMY,

THURSDAY, JUNE 7, 1838.

BY

OLINTHUS GREGORY, LL.D.

&c. &c. &c.

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TO

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THIS LECTURE IS INSCRIBED,

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THAT WILL EVER BE FELT IN THEIR WELFARE,

BY THEIR SINCERE FRIEND,

THE AUTHOR.

FAREWELL LECTURE,

&c. &c. &c.

In addressing you, Gentlemen, as I now do, for the last time, I shall, instead of giving a practical recapitulation of the scientific topics which have passed in succession before us during the Course now terminated, present to your consideration a few remarks with a view to stimulate the inquiries of those who have recently commenced their attendance in the Lecture Room, as well as to encourage the more enlarged and comprehensive researches of those who have tasted some of the pleasures and advantages of knowledge; and conclude with such directions as to mental exertion, culture, and discipline, as may not be inappropriate on this occasion.

The genuine object of all sound education is the development of the intellectual, the moral, and the bodily faculties of man; or, as it has been sometimes more tersely expressed, the improvement and application of *head*, *heart*, and *limb*. The system of education in the institution in which you have the honour to receive instruction, embraces all this. The blame will be your own, and it will through life be the subject of regret, if any of you quit this Academy without having acquired

the manners of a gentleman, the principles of a man of honour and high and pure morality, the ornamental facilities of an artist, and a competent store of literary and philosophical knowledge.

I am not actuated by any narrow sentiments of exclusive attachment to my own profession, when I affirm that mathematical and philosophical acquirements ought to rank high in your classification of the objects of mental research. The simple explication of the term PHILOSOPHY, carries with it an evidence of its utility. It is *the study of natural phenomena, or of phenomena artificially produced, in order to discover the forces which produce them*, though not their hidden causes. In the production of these phenomena, bodies manifest various properties: and it is in investigating the laws which regulate the exercise of those properties, that we rise to the invention of theories, which serve to connect the facts one with another, to show their mutual dependence, and enable us to make the powers of nature and the works of art, subservient to the purposes of men. The Supreme Being has created a world for our use, and us, in a measure, for its enjoyment; but, in order that we may use it successfully, and enjoy it adequately, we must cultivate our own intellectual powers, and this *depends upon* OURSELVES. Be it remembered, too, as you go along, that knowledge is *slow* in its acquisition, because it does not depend upon our senses, which are quick, or upon our wishes, which are boundless; but upon the order in which we trace the phenomena nature exhibits to us; and these we must generally content ourselves with soliciting from her by experiment, and analyzing and arranging as she spontaneously presents them.

To speak still more explicitly:—since all being reposes on the One Great Being, who originally created and ever sustains it, to work his will, the whole history of nature may well be expected to transcend our comprehension: yet that history, whether contemplated in reference to design or execution, is but one picture of wonder, of sublimity, of beauty, and especially of wise contrivance, the principal features of which it is delightful to trace. Whether we succeed or not in disclosing the hidden springs of all that is so exquisite, the most instructive comparisons are suggested. Thus we soon learn that no workman, however expert, can ever, in point of adaptation, either simple or elaborate, come near to the contrivances of the eye, of the ear, or of the joints, muscles, valves, which anatomy presents to our contemplation; and that no human wisdom can ever reach the appropriation of means to ends, exhibited by instinct; that a spider, a silkworm, a mole, a bee, or an ant, may confute an atheist; that the beaver evinces skill surpassing that of any human architect; that a muscle with its cable and anchor may excite more reasonable wonder than a ship. And, with regard to the heavenly bodies themselves, we feel that it is not their magnitude, brilliancy, beauty, or the unbroken order of their revolutions, that excites our highest admiration, but the persuasion that even they, both in their stations and their motions, are made subservient to human good; while all of them are so many irresistible witnesses of the *sustaining* providence of the GREAT SUPREME.

Let the works of nature, then, as well as the works of art, while they call forth your admiration, call forth, also, a desire to explore them, and thus tend to exercise and improve the habit of steady and successful

research. In a thousand instances, which will occur as you proceed, you must do more than gaze and wonder; the rudest peasant can do that:—*you* must inquire, must investigate, must have recourse to reasoning, to observation, to experiment.

Take, for example, a grain of mustard-seed and a grain of gunpowder; is there any thing in the colour, size, weight, or other sensible qualities of these respective substances which would enable you, *in limine*, to predict that a spark falling upon a heap of the one would be extinguished, while if it had fallen upon a heap of the other, it would have produced sudden and destructive conflagration? No: this knowledge is not a result of passive inspection, however patient. But the youngest boy that ever fired off a squib or a cracker, and knew something of its structure or composition, from that moment ascertains an important quality of detonating substances; nor ever after will you detect him, child as he may be, loading a pistol with mustard-seed, or sowing gunpowder in a garden.

A single experiment, then, happily selected or carefully conducted, *may* lead to a momentous discovery; yet, in the usual routine of scientific deduction, it is advisable, nay, it is often *necessary*, to trace our way by a cautious and judiciously conducted process. It may, indeed, be laid down as a universal maxim, that there is no infallible, and at the same time, *easy* method of attaining either excellence or eminence. There are no by-paths to the temple of philosophy. The small portion of learning or science which is attainable by the help of facilitating expedients, is but a temporary, as contrasted with a durable edifice—a tent contrasted with a castle. It is as unreasonable to hope to acquire

knowledge, without undergoing the labour by which it has been usually gained, as it would be to expect that an acorn will become an oak without passing through the ordinary process of vegetation. We build up our knowledge, augment our pleasure, and perfect our nature, by struggling with and surmounting obstacles; and the earlier you assume this as a practical maxim, the better.

It is one thing, however, to be, if I may so speak, the intellectual creator of a department of science, by invention, by discovery, and a due concatenation of principles and propositions; and another, and happily a much easier thing to *learn* a science so as to comprehend it in all its bearings and applications. Nothing beyond the ordinary powers of mind is requisite to study successfully any branch of philosophy. Facts, which are the materials of science, may be recollected and classified by him who has not opportunity to collect them; experiments may be understood by him who probably could not make them; and a logical system of scientific truths, appropriately demonstrated, may be studied with delight, and thoroughly comprehended, by one who is altogether incompetent to write a treatise; it being, in truth, this obvious difference in the scale of acquisition, that constitutes the main distinction between the pupil and the preceptor.

Thus much being premised, I invite your attention to a rapid sketch, principally historical, in which my desire is, partly to direct your researches, partly to gratify curiosity,—but much more, I confess, to *excite* it,—to stimulate to inquiry and exertion, by showing, in a brief selection, what has been, and what may again be, their noble reward.

There is implanted in the minds of all men of an inquisitive turn, an inextinguishable desire to penetrate to the origin of things; and there can be no doubt that such a desire, properly regulated, and judiciously directed, may be productive of beneficial results. It may teach us at once the strength and the weakness of human reason; may prove that though the regions of knowledge are extensive, rich, indefinitely diversified, and incessantly augmenting, they are, notwithstanding, limited. In surveying the present and past state of science and art, it is extremely difficult to make such a separation between what *is* known, and what *was* known, as shall preserve us from imputing to mankind in any given place and period, erroneous measures, either in kind or degree, of theoretical or practical acquisition. The obvious consequence is, that we are too apt, notwithstanding the utmost caution, to suppose them ignorant of matters which they well understood, or conversant with others with which they were unacquainted; to infer, in short, their knowledge from our own, to try *their* conduct by *our* standards, and thus often to censure, where we ought to applaud.

If we attempt to pass to any of the extreme points, towards which the understanding is often solicitous of elevating itself, we shall find much that is exhilarating, not a little that is perplexing. Take for a topic of meditation, the *first* of any series; the first man,—the first ear of corn,—the first day,—the first night,—the first solar eclipse: examine it in itself, trace it in its relations, dependencies, and results, and how soon will the most capacious intellect be lost in the speculation. Take, with this view, the first man, endeavour to depict his thoughts or his feelings, on the first day or

the first sun-set, or on first hearing his own voice, and you will find it difficult, even if you can reach his probable conceptions, to select adequate language in which to describe them.

In tracing the progress of science, the difficulty is too often of another kind. We are not so much at a loss, to ascertain what was early known with regard to any department of scientific research, or to describe it to others when ascertained, as to mark the chronological steps in the series, to show the numerous gradations by which it may have passed from its rude, or accidental, or imperfect origin, to the mature state in which we now behold it, and from which we are incessantly deriving so many advantages. Much, it is true, has been done in this respect, but much more remains to be accomplished. The simile of a bridge of numerous arches, by which human life has been sometimes aptly illustrated by the moralists, might, with a simple inversion, be applicable to what is before us: *there* the whole of the bridge is seen, except its extremities, which are pictured as enveloped in clouds; *here* the extremities are illuminated, while mists and fogs hang over many portions of the intervening space. It may, however, be useful, especially to the younger votaries of philosophy, to fix the attention for a while upon the extremities which are most plainly marked; to contrast the appearance of the early germ with that of the mature plant; to meditate upon the astonishing difference between the first thought and the expanded series of deductions from it, between the naked, insulated propositions which were first educed, and the complete system of which they at present form perhaps a very inconsiderable part. Such is the object

to which I would now direct your attention: and as I am unwilling to occupy too much of your time, I shall endeavour to make appropriate selections.

I commence with the subject of pure mathematics, which we may truly characterise, in the language of Dr. Barrow, as that which "effectually exercises, not vainly deludes, nor vexatiously torments studious minds; which overcomes without opposition, triumphs without pomp, compels without force, and rules absolutely without the loss of liberty; which does not covertly overreach a weak faith, but openly assaults an armed reason, obtains a total victory, and puts on inevitable chains; which obtrudes no false science, but very science itself, the mind, as soon as possessed of it, firmly adhering to it, and never after deserting it of its own accord; nor can it be deprived of it by any force of others." Among the earliest promoters of mathematics was the celebrated PYTHAGORAS, author of the appellation *Philosopher*, and "rendered immortal in the annals of geometry," say the historians, by the invention of the multiplication table, and by the discovery of three propositions, viz. that only three regular plane figures, the equilateral triangle, the square, and the hexagon, can fill up the space about a point; that the sum of the three angles of every plane triangle is equal to two right angles; and that in any right angled plane triangle the square on the longest side is equal to the sum of the squares on the two other sides. The discovery of this last proposition excited in the mind of Pythagoras such ecstatic and devout feeling, that he is described as offering a hecatomb to the gods on account of it. This I am inclined to disbelieve, for the reason assigned by Cicero, "that it was inconsistent with his principles,

which forbad bloody sacrifices." But, if the story be, as is probable, a mere fiction, it still serves to mark the state of mathematical knowledge, when a proposition which, however fertile in its consequences, is now placed among the lowest elements, should be characterised as the most brilliant discovery of the great man to whom we owe it.

It does not comport with the nature of an address like the present to contrast these in detail with the modern state of geometry, of algebra, of fluxions, and the differential and integral calculus, of the trigonometrical analysis, of logarithms and exponentials, of series, of rectifications, quadratures, cubatures, tangencies, points of contrary flexure; together with the sublime researches in the theories of partial differences, isoperimeters, and variations. Much less can I attempt to sketch their diversified applications to mixed mathematics, and the contributions which have thus been made to the arts and commodities of civilized life. But on these you will be called to enlarge as suitable opportunities occur, in the pursuit of your studies here.

Leaving then this inexhaustible general topic, let us descant on a few particulars drawn from several departments of science; taking first, that of the pressure and motion of liquids. Every one who hears me will recollect the story of Archimedes's exultation when he discovered the principle by which might be detected the fraud of the goldsmith who made Hiero's crown. An accidental thought, suggested while he was bathing, led to the investigation of a series of propositions, enunciated and demonstrated in his two books, "*De Insidentibus in fluido*," now extant. The nine propositions demonstrated in the first book relate to the principal laws and

circumstances of bodies floating on liquids, or sinking or rising in them; such as are now placed in the elementary inquiries respecting specific gravity. The second book comprises ten propositions, serving to ascertain the different positions which would be assumed by a parabolic conoid in a liquid; according to the different relations of the axis to the parameter, and to those of the specific gravities of the conoid and the liquid. The strictness and elegance of the demonstrations accord with the highest conceptions that can be formed of the powers of that extraordinary philosopher; but they relate to truths which now sometimes constitute the amusements of school-boys. Contrast them for a moment with the present state of hydrostatics and hydrodynamics; with the fine chain of researches which relate to the equilibrium and pressure of liquids and elastic fluids, whether simple or mixed,—the stability of floating bodies,—their motions and oscillations when the equilibrium is disturbed,—the general principles which determine the operation of liquids in motion, or of liquids affected by solid bodies in motion,—the operation of pumps,—the discharge of liquids through orifices in the bottom or sides of vessels,—the motion of water in rivers, canals, open or closed pipes,—the construction of flood-gates, sluices, dams, and banks,—the oscillatory motion of liquids in syphons and other tubes,—the percussion and resistance of liquids, with their application to the motion of water-wheels of different kinds, to the structure and manœuvre of vessels, and the entire practice of seamanship. How rich and diversified such inquiries; how vastly surpassing the discoveries of Archimedes in hydrostatics, must be evident even from this bare enumeration: but these, momentous as they

are, sink much in grandeur and importance when compared with the sublime investigations of Laplace in reference to the flux and reflux of the tides, and the stability of the equilibrium of the ocean. Although, in the indefinite variety of disturbance to which the ocean is liable, from the action of irregular causes, it may *appear* to return to its former state of equilibrium; yet a theorist inclined to speculate and not qualified to investigate this profound subject thoroughly, may apprehend that "some extraordinary cause may communicate to it a shock which, though inconsiderable in its origin, may augment continually, and elevate it above the highest mountains." Now Laplace, by means of an elegant and refined analysis, has developed the conditions which are necessary for the absolute stability of the ocean. He has shown irrefragably, "that the ocean is in a state of stable equilibrium; and if, as can scarcely be doubted, it has formerly covered continents which are now elevated much above its level, the cause must be sought elsewhere than in the defect of its equilibrium. His analysis also shows that this stability would cease to have place if the mean density of the sea *exceeded* that of the earth; so that *the stability of the equilibrium of the ocean, and the excess of the density of the terrestrial globe above that of the waters which cover it,* are reciprocally connected the one with the other."

What *we* term *accident* produced the train of thought in the mind of Archimedes, which issued in the elegant though simple propositions contained in his work; and these again in the expanded series of verities to which we have so briefly adverted. But this is by no means the only case in which accident has opened to us an extensive field of instruction and delight. Whether it

can be fairly inferred from some well-known passages of *Seneca*, *Pliny*, and *Pisidas*, that the ancients were acquainted with the power of glasses to magnify objects, or to make remote objects appear near; or, whether *Roger Bacon* and the monks of his time advanced farther than the construction of spectacles, are questions to which, however interesting they may be, we need not here devote any time. It suffices for my present purpose to remark that both *telescopes* and *microscopes* were unknown to the philosophers of the sixteenth century; and that a fortunate occurrence led to their invention, and to the grand and rapid extension given, in consequence, to the physical sciences. Borelli informs us, in a treatise composed not so long after the circumstance as to render his authority doubtful, that the children of Zachariah Jansen, a spectacle-maker of Middleburgh, amusing themselves in their father's shop, placed by chance a convex and a concave lens in such a manner that on looking through them at the weathercock of the church, it seemed to them nearer and much larger than usual. The father was called to witness this, and immediately fixing the glasses upon a board, that their relative position might be rendered permanent, he presented either those or others similarly arranged to his patron, Prince Maurice. The first telescope after these, which he made, was in the year 1590, and it did not exceed sixteen inches in length. No sooner was this remarkable discovery announced than Galileo, Kepler, and other philosophers, bent the whole force of their genius to the improvement and employment of so useful an apparatus; and since that epoch, theoretical and practical men have vied with each other in improving its construction and extending its powers. The posses-

sion of so noble an instrument—an eye which pierces to the regions of the stars—has given to astronomical researches a relish and a success unknown before. That "broad and ample road, the galaxy," has been ascertained to be, as the poet conjectured, "powdered with stars." The faces of the moon and the planets furnish as much delight to the observer as the contemplation of a rich and most diversified landscape: the satellites which attend some of the planets in their course become discovered; the magnitudes, distances, orbits, and motions of the bodies constituting the solar system, become correctly appreciated; the greater accuracy of astronomical observations furnishes new employment for theorists; these again suggest new occupation for the observer; their joint labours tend to the perfection of modern astronomy; and theory and practice so illustrate, assist, and confirm each other, that some of the phenomena of the remotest bodies in the planetary system, computed *years* before their occurrence, are found, in the event, to happen *at the time specified*, to within the interval of a clock's beat! How exquisite a result of so simple an incident as boys playing with spectacle glasses in the shop of an illiterate mechanic!

Nor is this all. The same happy occurrence placed with analogous rapidity in the hands of the natural historian an instrument, the microscope, which has enabled him to explore, with equal gratification and success, many of the minutest objects of creation, whose nature, economy, and uses, might otherwise have been for ever concealed. The "wonders of the microscope," indeed, can scarcely be described without an appearance of hyperbole. I shall only venture upon one sketch of

this kind; assuring you that, though my author has not altogether restrained his imagination, his descriptions, on the whole, accord with truth.

"The principal flower," says he, "in this elegant bouquet was a carnation, the fragrance of which led me to enjoy it frequently and near. The sense of smelling was not the only one affected on these occasions: while that was satisfied with the powerful sweet, the ear was constantly attacked by an extremely soft but agreeable murmuring sound. It was easy to know that some animal within the covert must be the musician, and that the little noise must come from some little body suited to produce it. I instantly distended the lower part of the flower, and placing it in a full light, could discover troops of little insects frisking and capering with wild jollity among the narrow pedestals that supported its leaves, and the little threads that occupied its centre. What a fragrant world for their habitation! What a perfect security against all annoyance in the deep husk that surrounded their scene of action! I was not cruel enough to pull out any of them for examination; but adapting a microscope to take in, at one view, the whole base of the flower, I gave myself an opportunity of contemplating what they were about, and this for many days together, without giving them the least disturbance. Thus could I discover their economy, their habits, and their enjoyments. With what adoration to the hand that gave being to these minute existences must a heart, capable of due warmth in his praise, see the happiness he has bestowed on them! The base of the flower extended itself under the leaves, and became trunks of so many stately cedars; the threads in the middle seemed columns of massy structure,

supporting at the top their several ornaments; and the narrow spaces between were enlarged into walks, parterres, and terraces. On the polished bottom of these, brighter than Parian marble, walked alone, or in larger companies, the winged inhabitants; these, from little dusky flies, (for such only the naked eye would have shown them,) were raised to glorious glittering animals, stained with lively purple, and with a glossy gold that would have made all the labours of the loom contemptible in comparison. I could at leisure, as they walked together, admire their elegant limbs, their velvet shoulders, and their silken wings; their backs vying with the empyrean in its blue; and their eyes, each formed of a thousand others, out-glittering the little planes on a brilliant—above description, and too great almost for admiration." How rich a treat for the lovers of nature! How little was it in the contemplation of Jansen's boys!

Compare for a moment the power of the telescope and of the microscope. The one enables us to refer a system to every star; the other leads us "to see a world in every atom. The one taught that this mighty globe, with the whole burden of its people, and of its countries, is but as a grain of sand on the surface of immensity; the other teaches that every grain of sand may harbour within it the tribes and the families of a busy population. The one indicates the insignificance of the world I tread upon; the other redeems it from all its insignificance; for it tells me that in the leaves of every forest, and in the flowers of every garden, and in the waters of every rivulet, there are worlds teeming with life, and numberless as are the glories of the firmament. The one has suggested that beyond and above all that is

visible to man, there may lie fields of creation which sweep immeasurably along, and carry the impress of the Almighty's hand to the remotest scenes of the universe; the other suggests that within and beneath all that minuteness which the aided eye of man has been able to explore, there may lie a region of invisibles; and that could we draw aside the mysterious curtain which shrouds it from our senses, we might there see a theatre of as many wonders as astronomy has unfolded, a universe within the compass of a point."*

Every person competently acquainted with English parochial customs, will be aware how long the force of steam must have been known, as evinced in the use of the village æolipile, distinguished by the name of "*Jack of Hilton;*" yet this custom, though continued from time immemorial, seems not to have suggested any useful invention. While the Marquis of Worcester was a state prisoner in the Tower,† some food being preparing on the fire of his apartment, the cover of the vessel being tight, was, by the expansion of the steam, suddenly forced off, and driven up the chimney. This led him to a train of thought, in reference to the practical application of steam as a first mover. The result of his speculations obscurely exhibited in his "*Century of Inventions,*" successfully wrought out by Sir Samuel Moreland, Newcomen and Cawley, Beighton, Boulton and Watt, and others, has at length terminated in that noblest example of mechanical ingenuity, as it now exists—the STEAM ENGINE. The whole operation of an engine of this kind depends upon two principles, the development of the elastic force of aqueous vapour by heat, and its sudden precipitation through the agency of cold,

* Chalmers's Astronomical Discourses. † In the year 1663.

principles which are simple and well known. But the different expedients for the transmission of the force thus obtained, as well as for increasing the force in what are called "high-pressure" engines, have greatly exercised mechanical ingenuity, and immensely augmented our stock of subordinate mechanism. No class of inventions has occasioned so entire a change in the construction and application of machinery as this; none has tended more to improve and complete the main processes in arts and manufactures; none more to facilitate the intercommunication between our manufacturing and other great towns; and consequently, none has more contributed to the commercial ascendancy of Great Britain in the scale of nations. Yet all this flowed, in the first instance, from an incident to which one can hardly make a formal reference without exciting risible emotions.

Physical Astronomy, again, as a department of mathematical theory, owes its origin to a simple accident. Sir Isaac Newton was forced from Cambridge in the year 1666 by the plague. During his retirement, his friend Dr. Pemberton states, as he was "sitting alone in a garden, some apples falling from a tree, led his thoughts to the subject of gravity." He was induced to conjecture that the moon was retained in her orbit by the same kind of force as that which caused the apples to descend to the earth, or that gave a curvilinear motion to bullets or other projectiles near the earth's surface. Ere long, he made a computation upon this hypothesis; and found that the deviation of the moon, moving in her orbit, from the tangent at any given point, was precisely what it ought to be, supposing the force of terrestrial gravity to vary inversely as the squares of the distances

from the earth's centre. This step accomplished, it was not for such a mind as Newton's there to rest. He collected "from mathematical reasoning, unexceptionably demonstrated, that all bodies which are moved in any curve line described in a plane, and which, by a radius drawn to a point, either quiescent or moved in any manner, describe areas round that point proportional to the times, are urged by forces directed to that point. And since it is agreed among astronomers that the primary planets describe about the sun, and the secondary planets describe about their primaries, areas proportional to their times, it follows, that the force by which they are continually deflected from the rectilinear tangents—are made to revolve in curvilinear orbits, is directed towards bodies placed in the centres of those orbits. This force, from whatever cause it may be supposed to arise, he thought might not improperly be called *centripetal* with respect to the revolving body—*attractive* with respect to the central body." But he uses great caution to prevent a misinterpretation of his meaning, which I mention here, because I have heard very confident arguments against his philosophy, founded on a mistake as to this point.

"What I call *attraction*," he suggests, "may be performed by impulse, or by some other means unknown to me. I use that word here to signify in general *any force by which bodies tend towards one another*, whatever be the cause; for we must learn from the phenomena of nature, what bodies attract one another, and what are the laws and properties of the attraction, *before* we inquire the cause by which the attraction is performed."

How immense and fertile the region of inquiry which

was thus laid open to the world, I need scarcely hint; yet who can be entirely silent on so magnificent a theme? The earth, the sun, and all the celestial bodies which attend the sun, attract each other mutually. The minutest particles of each of them, and of all other bodies, conform to the same law; each particle acting proportionally to its quantity of matter directly, and to the squares of its distances from other particles reciprocally. Hence flow a variety, not yet, nor perhaps ever to be, exhausted, of interesting and important propositions. Such, for example, as those which relate to the attraction of spheres, spheroids, and other solids, whether homogeneous or not, upon particles in assigned positions; the forces which retain the planets in their orbits, so as to conform to the Keplerean laws; the forces which disturb the elliptic motions of the planets and satellites; the irregularities of the lunar motions, and those of the other secondaries;—the mutations of the planes of the several orbits;—the figure of the earth and planets;—the variations of gravity at different points on their surfaces;—the tides;—the oscillations of the atmosphere;—the variations of atmospheric pressure at different altitudes;—the refraction of light while passing through the atmosphere;—the attractions of mountains;—the precession of the equinoxes, and the nutation of the earth's axis;—the irregular figure and balancing of Saturn's ring, and the dependence of that balancing upon that irregular figure;—the libration of the moon;—these and many more topics of investigation springing from the theory of attraction, and each and all of them, as they are pursued, supplying greater or less confirmation of the existence, "the simple and sublime agency, of this commanding principle."

By this principle philosophers have, so to speak, decomposed the physical system of the world, reduced it to its single element, and then re-composed it. Viewed in this relation, physical astronomy is, unquestionably, of all the sciences, the most complete, the most sublime, and that in which the human intellect is most elevated. "But that which gives it, above all, an inestimable value, is its *perfect certainty*." Other branches of science have changed incessantly, and several must still undergo modifications, several perhaps be abandoned: yet, whatever be the progress of knowledge, whatever the expansion of intellect, the principle of universal gravitation is established irrefragably, and the main deductions from it rest on an immovable foundation.

Before I quit this subject, I venture upon one more observation. It has been demonstrated by Lagrange and Laplace, having been on some points preceded by T. Simpson, Clairaut, Frisi, and others, that *all the planetary inequalities are* PERIODICAL, *each returning after a certain time, to go through the same series of changes which it had formerly exhibited;* the whole system oscillating, as it were, between certain limits which it can never pass. Now, this property, so essential to the well-being of the inhabitants of the several planets, requires the concurrence of these four, *independent*, conditions:—that the force shall be inversely as the square of the distance,—that the masses of the revolving bodies be small, compared with that of the central body,—that the eccentricities of the orbits be inconsiderable,—and that the planes of those orbits be originally not much inclined to each other. The irresistible conclusion thus furnished is, that *all this is the work of intelli-*

gence and design, for a benevolent purpose; the work of a controlling and regulating Power, from whom all the powers of material nature emanate.

Now, let any thoughtful person reflect on these and many other analogous facts; let him trace the links of the extended chain, "which connects the inquiries of Euler with those of a priest of Memphis," and he will inevitably perceive, not only how much we owe to apparent accident, but how the discoveries, which in one age were confined to the studious and enlightened few, constitute in the next the established creed of the learned, while in the third they form part of the elementary principles of education. He will also farther perceive the truth of Condorcet's observation, that "at the moment when a multitude of particular solutions, and of insulated facts, begin to distract the attention, and to overcharge the memory, *the former gradually lose themselves in one general method, and the latter unite in one general law;* and that these generalizations continually succeeding to one another, like the successive multiplications of a number by itself, have no other limit, than that infinity which the human faculties are unable to comprehend."*

* Qu'il me soit permis de présenter à ceux qui refusent de croire à ces perfectionnemens successifs de l'espèce humaine un exemple pris dans les sciences où la marche de la vérité est la plus sûre, où elle peut être mésurée avec plus de précision. Ces vérités élémentaires de géométrie et d'astronomie qui avaient été dans l'Inde et dans l'Egypte une doctrine occulte, sur laquelle les prêtres ambitieux avaient fondé leur empire, étaient dans la Grèce, au temps d'Archimède ou d'Hipparque, des connaissances vulgaires enseignées dans les écoles communes. Dans le siècle dernier, il suffisait de quelques années d'étude pour savoir tout ce qu'Archimède et Hipparque avaient pu connaître; et aujourd'hui deux années de l'enseignement d'un professeur vont au-delà de ce que savaient Leibnitz ou Newton. Qu'on médite cet exemple, qu'on saisisse cette chaîne que s'étend d'un prêtre de Memphis à Euler, et remplit la distance immense qui les sépare; qu'on observe à chaque époque la génie devan-

I might now pass to *Voltaic Electricity*, and show, from the testimony of Biot, Galvani, and Haüy, that this new branch of science,—a branch which, under the culture of Davy and his numerous successors, has been made to contribute largely to our store of chemical and magnetic facts and doctrines,—may be traced to what Bacon terms "the *fortune* of experiment." But, lest I should far overstep the appropriate bounds of this address, I must satisfy myself with this mere allusion, and proceed to my last selection.

In *Physiology*, as in Physics, we have occasionally been more indebted to accident—to a happy, though perhaps at first an erroneous thought—than to the profoundest study, or the best conducted train of experiments. One of the most curious, as well as of the most important functions of the animal economy, is that of *digestion*, the real nature of which was fallen upon in this manner. Considering the comparatively slender texture of the stomach, and the toughness and solidity of the substances it is capable of digesting, it cannot appear surprising that mankind should have indulged in a variety of theories, and run into a variety of errors, in accounting for its mode of action. Empedocles and Hippocrates ascribed the process to a power, possessed by the stomach, of decomposing the food by a rapid

çant le siècle présent, et la médiocrité atteignant à ce qu'il avait découvert dans celui qui précédait, on apprendra que la nature nous a donné les moyens d'épargner le temps et de ménager l'attention, et qu'il n'existe aucune raison de croire que ces moyens puissent avoir un terme. On verra qu'au moment où une multitude de solutions particulières, de faits isolés, commencent à épuiser l'attention, à fatiguer la mémoire, ces théories dispersées viennent se perdre dans une méthode générale, tous les faits se réunir dans un fait unique, et que ces généralisations, ces réunions répétées n'ont, comme les multiplications successives d'un nombre par lui-même, d'autre limite qu'un infini auquel il est impossible d'atteindre."—*Condorcet—Sur l'Instruction Publique.*

putrefaction: Galen, to its decomposing it by a peculiar accumulation of heat, during the time of digestion: and Macbride and Pringle long afterwards, to the action of fermentation; thus combining the two causes assigned by the Greek writers. Grew and Santarelli embraced the doctrine of a concoction, by the various juices that are poured into the stomach from the liver, the spleen, and other organs; while Pitcairn, and all the mechanical physiologists, contended that it was accomplished by a process of trituration, occasioned by an enormous mechanical pressure of the muscular coat of the stomach upon its alimentary contents, which they were fanciful enough to calculate, the minutiæ of the computation being detailed in some of their works, to act with a force exceeding 117,000 *pounds*, assisted at the same time in its gigantic labour, *by an equal force* derived from the surrounding muscles.

Reflecting men, however, were still dissatisfied. Each of these theories was found to be encumbered with difficulties of its own, while all of them were alike incompetent satisfactorily to explain the fact for which they were invented. At length Cheselden threw out the fortunate hint, that possibly digestion might be accomplished by means of some peculiar solvent, secreted by one or other of the digestive organs: and he directly pitched upon the saliva, or the fluid secreted by the salivary glands.

The hint was eagerly seized and followed up by Haller, Réaumur, Spallanzani, and others; and though it was at once seen that Cheselden was under a mistake as to the particular fluid, yet a fluid of a most wonderful solvent power was soon detected, secreted from the internal surface of the stomach itself, and its

singular properties were satisfactorily ascertained and established.

This extraordinary menstruum, the most active with which we are acquainted in nature, is now well known by the name of *gastric* juice, so called from the Greek term for the organ that pours it forth.

Its apparent simplicity of composition is as remarkable as its digestive power; for, in a pure and healthy state, it is a thin, transparent, and uninflammable fluid, of a weak saline taste, and utterly destitute of smell. Its antiputrescent property is of as extraordinary a nature as its digestive; for it will render perfectly sweet the most offensive and putrid food that gipsies or hungry dogs can be made to swallow, in about half an hour after such food has been exposed to its action. This gastric juice farther possesses, in an equal degree, both these curious powers of dissolution and restoration to sweetness, as well out of the body as in the stomach itself.

I present this example, that you may trace the origin of the mistakes into which theorists are often apt to fall in their speculations upon the causes of things. Measuring the operations of nature by their own imperfect powers, they take it for granted that that which appears to be elaborate, must, in fact, *be* so. Hence, in tracing her, they overlook the principle of simplicity which is stamped upon her footsteps; surround themselves with a complex machinery; and lose their aim and their path by the mere multiplicity of their agencies; till accident, in a lucky hour, points out the right, the long-sought track.

We have seen, in the principal cases which I have selected, how much has sprung from *apparent* accident.

I must not, however, omit to tell you that, in my deliberate judgment, it was only accident in *appearance.* How many thousand persons before Newton had seen an apple fall, with respect to whom the observation had been altogether unproductive? Besides the event of the falling apple, there needed the simultaneous operation of various independent causes to render it an epoch in the history of philosophy. It was necessary that it should be observed by a man at *leisure* to pursue any train of reflection that should thereby be suggested; it was necessary that it should be noticed by a man of *research,* and that—not as a lawyer,—not as a theologian,—not as an anatomist, a botanist, an entomologist, or a chemist, but as *a mathematical philosopher.* It was farther necessary that the observer should have a certain fund of previous knowledge, and yet, that his mind should not be *pre-occupied.* Had the falling apple been observed by Newton when he was absorbed in his admirable investigations concerning light and colours, it might no more have led to the theory of universal attraction and the perfection of physical astronomy, than it would in the contemplation of the most illiterate porter that paces our streets. Let us view these matters aright. It is not *chance,* but *previous design,* that in this and other similar instances, brings so many independent circumstances into juxta-position; just as in the case of two travellers,—one passing from London northwards, the other from York southwards,—meeting on the way, the *accident* of their meeting is a necessary consequence of the previous *determinations* of both to start at a certain time, and to travel by the same road.

The practical inference we may draw from the whole,

and which I would strongly urge upon your attention, is simply this:—Do not *hastily* relinquish a train of thought, suggested by a fresh class of circumstances more or less interesting, even though the prospect of utility be very remote. If the poet spake truly, that "our thoughts are *heard* in heaven," may not a philosopher remark with equal truth, that our noblest thoughts are *suggested* in heaven; and that all genius is a species of inspiration? Among the ancients, when nature was not, as too frequently happens among us, concealed under a thick veil of elucidation, this was unhesitatingly admitted; as by *Plato* in his *Phædrus*, and even by *Longinus*, the most reserved of ancient critics. They distinguished accurately the enthusiasm or inspiration of genius, from the perturbed suggestions of the Θεοληπτοι and *Phrenetici;* but sought the occasion of both *ab extra*, and not in the imagination itself. In the latter case, they regarded the bark as driven of *necessity*, wanting cable and anchor to hold her; in the former, as sailing from *choice*, because the gale is from a favourable quarter, and the voyage desirable. Under another metaphor they viewed the imagination of the poet, and in its kind and degree, that of every man of genius, as a field in which the Author of nature produces a set of objects which existed not before; as a region in which new images and combinations arise, like new plants, under auspicious circumstances of culture or climate, according to the settled laws of the Creator. Notwithstanding, however, the exhaustless fertility of the field, we are placed in it as *labourers*, amid circumstances which show that though nature is liberal in *supplying* her gifts, she seems so parsimonious in their *distribution*, that none but the vigilant obtain them;

thus teaching how entirely it behoves us to avail ourselves with promptness, and to the utmost, of the circumstances into which we are thrown.

Distinguish, then, with the most watchful scrutiny, between the dictates of wisdom and of folly, the suggestions of reason and of fancy; but do not abandon a train of inquiry, merely because it seems likely to produce but *little.* When you call to mind how many valuable results have been obtained by the aid of the thermometer, for example, that is, of a little mercury enclosed in a slender glass tube, and recollect that a small piece of magnetized iron suspended on a pivot led to the discovery of the Western World, you will perceive that nothing which tends, even remotely, to augment and perfect the intellect of man, or to increase his resources, is of trifling consideration.

Remember that lofty trees grow from diminutive seeds; copious rivers flow from small fountains; slender wires often sustain ponderous weights; injury to the smallest nerves may occasion the most agonizing sensations; the derangement of the least wheel or pivot may render useless the greatest machine of which it is a part; an immense crop of errors may spring from the least root of falsehood; a glorious intellectual light may be kindled by the minutest sparks of truth; and *every principle is more diffusive and operative by reason of its intrinsic energy than of its magnitude.*

I will remind you of some of the practical maxims which I have at different times impressed upon you, annex a few others, and then conclude.

I. With regard to intellectual inquiry and conviction generally, do not suffer yourselves to be bewildered or perplexed by the attempts of sophistical or bad

reasoners to assign to one class of evidence the cogency which belongs to another, and perhaps to that alone. History has one kind of evidence; mathematics another; and you have often been shown in what consists its peculiar value, and whence its appropriate force, its indubitable certainty, flow. So again, another kind of evidence belongs to natural philosophy; while the philosophy of human nature and of morals has another quite distinct from all these. The subordinate branches of the several parts have still minuter peculiarities in the evidence appropriated to them. Now, an enlarged and unprejudiced mind will, in each of these, yield his conviction to that species of argument and that kind and measure of evidence which manifestly accords with the subject before him; and no man can fairly claim the title of a sound reasoner who employs or expects, with regard to a historical fact, the evidence which he requires in confirmation of a geometrical truth. You know very well that *testimony* is not admitted in proof of any mathematical proposition, because mathematical evidence is of a totally different kind. Yet mathematicians are not the only persons who exercise a rational belief. In natural philosophy, a science in various respects scarcely, if at all, inferior to pure mathematics in the certainty of its conclusions, you receive testimony as an ample proof of many facts. It is, therefore, agreeable to reason and sound philosophy, to accredit cautiously analyzed testimony. Besides which, it is demonstrable on mathematical principles, that the *concurrent* testimony of competent witnesses may, in numerous instances, furnish evidence, which is really irresistible, of the most extraordinary and improbable events.

II. Nor, again, must you suffer yourselves to be seduced

into the too hasty adoption of trite and current maxims, however prevalent they may be. Let these, also, be carefully scrutinized, to ascertain whether or not some specious sophism may not lurk beneath them. To cite a striking example:—A maxim of this kind, which lies at the basis of the Cartesian philosophy, and which for some time was almost universally received, was couched in the terms, "*Ego cogito, ergo sum—I think, therefore I exist.*"* This being expressed with epigrammatic point and terseness, aptly insinuates itself into the mind; yet it is palpably a sophism, a *petitio principii.* The very thing to be proved by it is taken for granted; for there cannot be thought unless the thinking being exist: and thus, in order to know that *I* think, I must first be persuaded that *I* exist; and, of course, to prove the fact of my existence by that of my thinking, is to reason in a circle. It is, in truth, equally evident that *I think* and that *I exist;* so that there is here no proof: and yet this example of false reasoning was worked into the very foundation of a philosophical system, which for a long time prevailed more universally than that of Newton.

* When I delivered this lecture, I participated in what, so far as I knew, was the general belief, that *Des Cartes* was the author of this celebrated enthymeme. But I have since found that a kindred maxim, expressed in less objectionable terms, occurs so early as in the works of *St. Augustine.* In opposing the Sceptics of his time, he says, "I do not perceive what mighty force there is in the scepticism of the Academics. For my part, I look upon it as a very just observation of theirs, that we may deceive ourselves. But if I deceive myself, may I not thence conclude that I am? For he who has no existence cannot deceive himself; wherefore, by that very circumstance, that I deceive myself, I find that I am."—*August. de Lib. Arbit.* l. ii. cap. 3. Probably this passage had been read by Des Cartes during his early studies under the Jesuits; and occurred to him afresh, long afterwards, with the modification it has received in his hands, without his being at all conscious that it was a modified reminiscence, and not an original thought.

What an instructive caution against the hasty reception of current phrases!

III. Bear constantly in view that the study of nature is, mainly, the study of facts, not of causes; and hence that the objects of philosophical science are, not to indulge in speculations and frame hypotheses,* but to observe facts, to trace the phenomena of nature, to fix their relations, and when possible, their order of succession, and to ascertain the facts that are universal. The efficient causes being almost always beyond the reach of the human faculties, are therefore not the legitimate objects of scientific inquiry.

In the deduction of general principles, the following have been laid down as safe and unobjectionable rules:—

1. That whatever is assumed as a principle be itself a fact, not an imaginary result of speculation.

2. That it be true, without a single exception, of all the individual cases; or, in other words, that the fact be universal.

The first of these rules is specifically opposed to the too prevalent habit of referring phenomena to fictitious principles. The second is equally opposed to the erroneous practice of hasty generalizing, or of inferring some universal proposition from a limited number of facts.

IV. In your efforts to store your minds, while you gather information from every source, exercise the utmost caution as to the soundness of the principles you adopt, or the authenticity of the facts which you admit;

* "Hypotheses non fingo," NEWTON remarks; "quicquid enim ex phænomenis non deducitur, hypothesis vocanda est. Et hypotheses, seu metaphysicæ seu physicæ, seu qualitatum occultarum, seu mechanicæ, in philosophiâ experimentali locum non habent."—*Princip.* lib. iii.

yet let there be an entire freedom from all such prejudices as would shut you up from the reception of truth from any and every quarter whence it may present itself.

Learn so correctly to appreciate things, that while you entertain the full persuasion that *professional* knowledge is essential to your success, you believe also that there is no species of knowledge but what may be turned to beneficial account. All, in truth, are parts of one grand whole, which, though they have been separated into distinct departments for their more ready and effectual cultivation, as well as that every individual may appropriate his own regions of investigation, according to his peculiar bias, are attached to each other by points of contact more or less numerous; so that light thrown upon one region inevitably sheds more or less of its illumination over others.

A single example may suffice for the illustration of this. From a momentary glance of thought you might be inclined to doubt if you were told that an intimate connexion subsisted between the sciences of anatomy and vegetable physiology, and portions of acoustics, chemistry, hydraulics, mechanics, optics, and pneumatics; and yet if you direct your thoughts a little onward, and wish to comprehend the structure of the eye, the nature of its separate "humours," as they are technically designated, and the theory of vision, you will at once perceive that you must have recourse to optics and chemistry; and, in like manner, to comprehend the structure and functions of the ear, you must have recourse to acoustics; to comprehend the force and operations of the joints and muscles, you must turn to mechanics; the study of the blood-

vessels and their valves, of the air-vessels and the lungs, and of the mechanical process of breathing, will compel your reference to hydraulics and pneumatics; while, to understand how it happens that between the successive expirations and inspirations there always occurs an interval which allows time for the two noxious fluids—nitrogen gas and carbonic acid gas—which are ejected at the same instant, to separate, the first to ascend as the other descends, the supply of a current of uncontaminated atmospheric air being meanwhile provided for;—and again, to seize the rationale of that striking arrangement in vegetable physiology, in consequence of which what is hurtful to man becomes beneficial to vegetables, at the same time that the oxygen which vegetables do not need is separated by them in its utmost purity for the use of man,—you must appeal for aid in part to chemistry, in part to pneumatics.

Pursuing such trains of inquiry, you will soon feel the importance of aiming to estimate the real and the relative value of the various sciences, as well as of tracing their mutual connexion and dependence; and hence feel, also, how desirable it is to arrange the objects of human thought in grand divisions. Whatever be the general classification which you adopt, carefully assign to each grand division its appropriate portion, weigh well its natural subdivisions, and assign to each of them its appropriate proportions also. Let the attempts at classification be, at first, entirely and exclusively your own; and after you have formed three or four such schemes, subject them to the inspection of some one who is experienced in matters of arrangement. From his suggestions and modifications you will gain a useful lesson, by learning the nature, the

origin, and the extent of your failures in these attempts; and by perseverance you will learn farther how to analyze the operations of your own mind, as well as so to classify the objects of knowledge, that they may best illustrate or establish each other, and thus more thoroughly prepare yourself for the treasuring up and the communication of truth.*

* In a recent lecture, in which we investigated the mathematical laws of the motion of pendulums, I expatiated, as you will recollect, on some of the relations suggested to us by the contemplation of physical phenomena, as those of space and time, force and motion, continued action and acceleration or retardation; and I called your attention to a few of the difficulties, physical and metaphysical, involved in the question, "What do you mean when you ask, *What o'clock is it?*"

I revert very briefly to the subject in this note, simply in order to remark that the various perplexities which have been grouped about all metaphysical inquiries into time, from the epoch of *Epicurus's* celebrated assertion, "Time is a mere event of the imagination;" or the kindred maxim of *Lucretius*, "Tempus item per se non est;" with the succeeding paradoxes, that time is "fleeting, and yet permanent;" "universally present, yet no where to be perceived;" that "time is anything, everything, something, nothing;" that "force and time have no relation;" that "motion is nothing real;"—all meet with probably the most consistent and intelligible solution in the language of the mathematical analysts.

"Donc, en général, dans tout mouvement rectiligne dans lequel l'espace parcouru est une fonction donnée du temps écoulé, la fonction prime de cette fonction représentera la vitesse, et la fonction seconde représentera la force accélératrice dans un instant quelconque; car comme les temps, les espaces, les vitesses et les forces sont des choses hétérogènes qu'on ne peut comparer ensemble qu'après les avoir réduites en nombres, en les rapportant chacune à une unité déterminée dans son espèce, nous pouvons, pour plus de simplicité, exprimer immédiatement la vitesse et la force par les fonctions primes et secondes, comme nous exprimons l'espace par la fonction primitive. D'où l'on voit que les fonctions primes et secondes se présentent naturellement dans la mécanique, où elles ont une valeur et une signification déterminées; c'est ce qui a porté *Newton* à établir le calcul des fluxions sur la considération du mouvement. Ainsi, l'espace, la vitesse et la force étant regardés comme des fonctions du temps, sont représentés respectivement par la fonction primitive, par sa fonction prime, et par sa fonction seconde; de manière que connaissant l'expression de l'espace par le temps, on aura tout de suite celles de la vitesse et de la force par l'analyse directe des fonctions; mais si on ne connaît que

Of course you will not neglect the *professional* classifications; but of these I am not now speaking; you will pursue them most advantageously under the especial guidance of the respective professors and masters of the Institution.

The principles of science, and the inductive habits of correct philosophical reasoning, will all along furnish you with considerable advantages, besides those that flow from the love of *absolute accuracy* in all things which they naturally tend to produce. By putting you in possession of a few general facts, philosophy will also enable you to determine, by correct and cogent reasoning, what will be the result of any supposed combination of them, and thus to comprehend an immense variety of particulars, which the most powerful and well-exercised memory could not so retain as to recall at pleasure. The knowledge of such general facts relieves you at once from the necessity of treasuring up in your memory *all* those truths which are involved in the principles you have established, and which may, without difficulty, be deduced from them by reasoning; for by means of what has been thus established, you may often prosecute your discoveries synthetically into various regions of inquiry to which you could never have access by imme-

la vitesse ou la force par le temps, il faudra alors remonter aux équations primitives par les règles de l'analyse inverse. Ces notions de la vitesse et de la force accélératrice sont, comme l'on voit, très simples et indépendantes de toute métaphysique.

"Elles sont fondées sur la nature du mouvement regardé comme le transport d'un corps d'un lieu à un autre. Si un corps demeure en repos, sa vitesse est évidemment nulle; mais il peut éprouver l'action d'une force accélératrice qui, étant arrêtée par quelque obstacle ne produit qu'une tendance au mouvement. Cette force est alors ce qu'on appelle *pression* ou *force morte*, et peut être comparée à l'action qu'un corps pesant exerce sur l'obstacle qui l'empêche de tomber."—*La Grange, Théorie des Fonctions analytiques*, p. 316.

diate observation. Many of the simple, yet comprehensive formulæ, to which your attention has been directed in your mathematical course, will, upon an analogous principle, facilitate your other researches in an extraordinary degree. And you have on former occasions been especially shown how essentially even the simple improvement introduced by Professor T. Simpson, (in 1757,) in the designation of trigonometrical functions, *sin. a*, *cos. a*, *tan. a*, &c., have conduced to the sublime discoveries of La Grange and La Place, to which I have already adverted in this Lecture.

Indeed, mathematics and philosophy abound with evidence of the advantages, as well as the beauty of scientific grouping and arrangement. You trace them, for example, in the connexion of the length of the second's pendulum in any place, with the lineal measure of the force of gravity as marked by the space described uniformly in a second unit of time, with the velocity acquired by a body falling freely during the first unit; and the rich train of results that are deducible from that connexion: you trace them in the admirable chemical technology introduced by Lavoisier, and in the theory of definite proportions: you trace them again in the reference of the specific gravities of all substances to that of pure rain water; in that of all temperatures to the measure supplied by comparing the temperature of boiling water and that of thawing ice; and in the investigation of the properties of curves of different *orders* by means of equations of different *degrees;* together with the *method of co-ordinates*, and its easy and elegant application to every department of mathematical physics.

V. While, however, scientific classification will relieve the memory of much of the burden which it would

otherwise have to sustain, you must not permit this circumstance to tempt you to undervalue that intellectual faculty, or to neglect its cultivation.

Assume it as an unquestionable truth that whatever is once deposited in the memory can never, while the understanding remains, be entirely obliterated. It may, by the obscurity of its traces, seem to elude the mental ken, but there it is, notwithstanding.* The *memory* is faithful to its trust; but the power of *recalling* may have been imperfectly cultivated; and in consequence the record of the fact or of the proposition which you seek remains in concealment, simply because you have not cultivated the art, or mastered the use of the instruments which would infallibly seize it, and raise it into light.

All that I have just been saying of grouping and classification receives one of its most valuable applications here; and *attention* and *association* are the main principles upon which the application depends. *Attention*, essential to the formation of the military character from first to last, is equally necessary to the cultivation and growth of the powers of memory. The distinct and easy recollection of any fact is usually proportional to the intensity with which it has been contemplated, and the watchfulness with which it has been deposited in the general receptacle. Attention is a voluntary act, influenced by previous intellectual habits, and therefore susceptible of steady and constant improvement by daily exercise. Even the occasional instances of forgetfulness which occur to every one, may have their use in quick-

* In proof of this, call to mind the fearful rapidity and vivid intensity with which a numerous and long-forgotten train of circumstances present themselves before you, on the death of a friend, or some other solemn event.

ening the exercise of attention; if, indeed, they are not in many cases essentially subsidiary to correct remembrance. Old ideas are revivified and made permanent by attentive periodical renovations of the impressions which time is always wearing away, and which newly-acquired facts or images are incessantly tending to obliterate.

Next in value to attention is *association*, a principle which necessarily holds an important place, and to which all scientific classifications are subservient; of which, in truth, they constitute a part. Almost every kind of association, natural or philosophical, local or incidental, arbitrary or fictitious, including under certain precautions a scheme of "artificial memory," has its use; and ought therefore to be cultivated with assiduity, discrimination, and care. This law of association, while it is peculiarly important with regard to memory and recollection, is also of high utility in suggesting both retrospective and prospective relations, as well as in serving to convince the student that while he prizes every accession to his stock of knowledge for its own sake, he may also regard it as a legitimate instrument for the acquisition of farther knowledge.

VI. Let not your mind become the mere passive receptacle of truth and science; but rouse it habitually to a state of *active* inquiry, constantly and sedulously engaged in searching out knowledge, and in ascertaining the meanings of terms and phrases, and the reasons of things. Connect with this mental activity, a love of truth,—skill in disentangling and separating it from all its counterfeits,—such a firm control over the imagination as may check its excursions into the regions of error, or its adoption of any principle or sentiment

which does not harmonize with truth,—a careful selection of the topics upon which the efforts of your minds may be usefully concentred; and therefore the cautious and unwearied exercise of a calm, independent, and sound judgment, which shall as safely and as successfully apply itself to the formation of opinions as of habits. And, with respect to the acquisition of knowledge, recall to your thoughts, what I have often told you, that the *easiest* way of arriving at truth is not always the *best;* but that, in matters of investigation, *one* addition to our store which results from our own efforts is ultimately of more value than *ten* gathered from the communications of others, because of its greater tendency to fix itself indelibly; and that, with a few exceptions (so few, indeed, that they need scarcely be taken into a practical estimate) *any person may learn any thing upon which he sets his heart:* to ensure success he has simply so to discipline his mind as to check its vagrancies, to cure it of its constant proneness to be doing two or more things at a time, and to compel it to direct its combined energies simultaneously to a single object, and thus *to do one thing at once.* This I consider as one of the most difficult, but one of the most useful lessons that a young man can learn.

But however difficult it may be, it is attainable. It is the practical result of a still more exalted attainment, "THE POWER OF MASTERING THE MIND." But if it be desirable to obtain and keep the ascendancy any where, it is, surely, *at home,* in the centre of your own intellect and its principles, your heart and its emotions. Gain the mastery here, govern within, learn to direct your thoughts to any subject you please, and keep them uninterruptedly to their occupation, till at *your* bidding

the labour shall be remitted: then all will be well, for all will lead to a prosperous issue. With a thorough persuasion that steady, well-arranged employment is the grand instrument of mental prowess and superiority, guard against listlessness, frivolity, and day-dreams; resort to the higher, the heavenly, springs of self-government, and ultimate success is yours. And, although I have, on this occasion, scarcely adverted to moral considerations, yet, you will, on the termination of our intercourse, permit me to remind you, that there is so fixed and indissoluble a connexion between moral conduct and intellectual progress, that whoever falls into irregular courses, or indulges evil propensities, will inevitably show it by his failures in study, and the crudeness and poverty of his acquisitions.

Finally. If knowledge, in its advance, dispels the darkness and perplexity of error, and you wish to expatiate with freedom and safety in the light of truth, —pursue it.

If knowledge, united with uprightness, bring esteem and confidence, and you love to be esteemed and confided in,—pursue it.

If "knowledge is power," and you love power and influence,—pursue it.

If knowledge carry in its train extended usefulness, and you love to be extensively useful in your profession and in the world,—pursue it.

If knowledge, as it becomes augmented, enlarges its own power of expansion; if the mere consciousness of progression makes your progress more continuous, and you feel the delights of a daily advance in knowledge,— pursue it.

If it be "heaven upon earth to have a man's mind

move in charity, rest in Providence, and turn upon the poles of truth," and sound knowledge in its various streams leads to this exhilarating confluence of good,—pursue it.

If knowledge, rightly conducted, and directed to right ends, brings you nearer to the Fountain of Knowledge, and thus makes you more happy, while it enlarges your capacity of conferring happiness upon others; and you love to be happy, and to confer happiness,—pursue it.

But, while you pursue it, let me entreat you to avoid most carefully the great error of mistaking or misplacing the ultimate object of knowledge. "For many," says Lord Bacon, "have entered into a desire of learning and knowledge; some upon an inbred and restless *curiosity;* others for *ornament* and *reputation;* others for *contradiction* and victory in dispute; others for *lucre* and living; *few* to improve the gift of reason given them from God, to the benefit and use of men. As if there were sought in knowledge, a *couch*, whereupon to ease a restless and searching spirit; or a *terrace* for a wandering and variable mind to walk up and down in, at liberty unrestrained; or some lofty *tower of state*, from which a proud and ambitious mind may have a prospect; or a *fort* and commanding ground for strife and contention; or a *shop* for profit and sale; and not rather a rich *storehouse* for the glory of the Creator of all things, and the relief of man's estate."

In your mental and scientific pursuits, then, define to yourselves clearly the purposes which you have in view: see to it that they are in no way incompatible with the nature, the duty, and the ultimate destiny of man, and you cannot direct your aim to too high a point. Re-

member that there is a susceptibility of incessant elevation in the human character, enabling us to pass from the animal man to the rational man, from the rational to the intellectual man, from the intellectual to the spiritual man—transformed into the Divine Image, and soaring to joys unutterable. And rest not, therefore, till you acquire a capacity of rising spontaneously from the contemplation of the sublime in matter, to that of THE SUBLIMEST in mind;—to that of the SUPREME REALITY, who comprehends all which he has made, and infinitely more than what as yet delights and interests us, within the scope of one grand administration;—to Him whose ineffable character "*gathers splendour from all that is fair, subordinates to itself all that is great, and sits enthroned on the riches of the universe.*"

And now, Gentlemen, with the most gratifying retrospect of the deferential and almost filial attention with which you have uniformly listened to my instructions, I cordially bid you farewell. May your career be long, untarnished, honourable, prosperous, and happy!

THE END.